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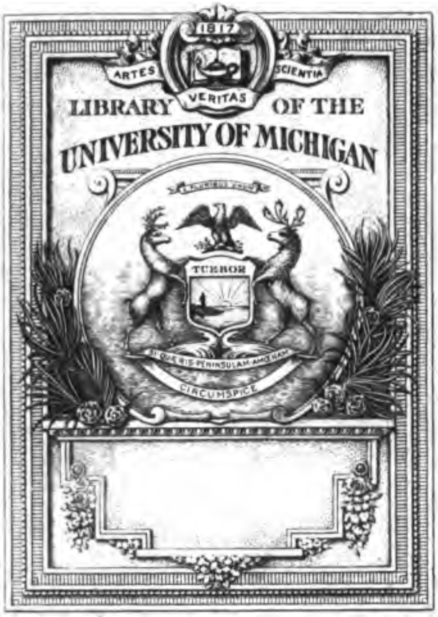

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DEFINITIONS AND EXPLANATIONS

OF

NAVIGATION

AND

NAUTICAL ASTRONOMY.

FOR THE USE OF NAVAL CADETS ON BOARD
H.M.S. "BRITANNIA."

SECOND EDITION

GRIFFIN & CO.,
(Publishers, by Appointment, to Her Majesty the Queen.)
2, THE HARD, PORTSMOUTH.
LONDON AGENTS:
SIMPKIN, MARSHALL & CO.,
1887.

CLARKE & SON
Printers
Booksellers & Stationers
to Her Majesty
45, FORE ST., DEVONPORT

PRINTED AT THE OFFICE OF THE PUBLISHERS.

MU

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Library
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PREFACE

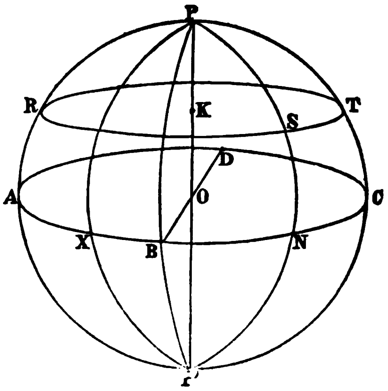
THIS BOOK OF DEFINITIONS represents an effort to collect, and systematize the principles of NAVIGATION AND NAUTICAL ASTRONOMY. The first Edition was compiled in consultation with a great many teachers of the subjects, and has had the advantages of criticism, extending over twelve years of work. The present Edition is the result of a renewed study of the best authorities with the co-operation and advice of the Naval Instructors of the Royal Naval College and of H.M.S. "Britannia"

No effort has been spared to make the wording of the Definitions as simple and obvious as could be. It cannot however be supposed that finality has been arrived at, and blank pages have been provided for notes and alternative definitions which may approve themselves to teachers. It is hoped that any such emendations will be communicated for future use.

J. CLEMENT P. ALDOUS.
Chief Instructor,
and Chaplain to Cadets.

H. M. S. *Britannia,*
August 27th, 1887.

A SPHERE AND ITS CIRCLES.



O is the Centre of the sphere ; OB a Radius ; PP′, BD Diameters.

ABCD is a Great Circle.

RST is a Small Circle.

PP′ is the Axis of the circles ABCD and RST ; and P,P′ are the Poles of those circles ; P the nearer to RST, P′ the further.

PBP′ and PNP′ are secondaries to ABCD.

BPN is a Spherical Angle, measured by BN.

RST is a Parallel to ABCD.

XN and NS are spherical co-ordinates which determine the position of S with respect to the fixed Primary ABCD and the fixed secondary PXP′

CHAPTER I.

THE SPHERE.

Sphere

Centre.

A Sphere is a solid, bounded by a surface, every point of which is equally distant from a fixed point called the *Centre.*

Radius.

A Radius of a Sphere is a straight line joining the centre to any point in the surface

Diameter.

A Diameter of a Sphere is a straight line passing through the centre and terminated both ways by the surface.

Section.

A Section of the surface of a Sphere made by a plane is a circle. (*Theorem*).

Great Circle.

A Great Circle is the section of the surface of a Sphere made by a plane passing through the centre.

Small Circle.

A Small Circle is the section of the surface of a Sphere made by a plane not passing through the centre.

Axis.

The Axis of a circle of a Sphere is that diameter of the Sphere which is perpendicular to the plane of the circle.

Poles.

The Poles of a circle are the extremities of its axis.

Secondary

A Secondary to a circle is a great circle passing through its poles.

Spherical Angle.

A Spherical Angle is the angle between two great circles.

Measure of a Spherical Angle.

A Spherical Angle is *measured*:—

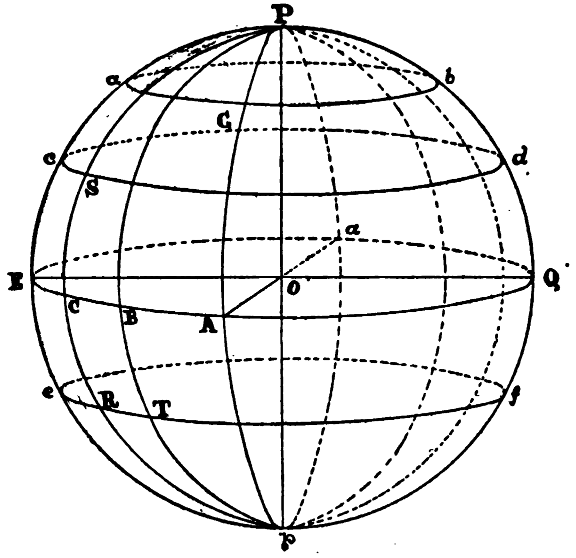
(1)By the angle between the tangents to the circles at the point of their intersection.

(2) By the angle between the planes of the circles.

(3) By the arc which the circles intercept on the great circle to which they are secondaries.

Parallel.

A Parallel to a great circle is a small circle whose plane is parallel to the plane of the great circle.



Pp is the Earth's Axis.

P and p are the Earth's Poles.

ECBAQ is the Equator.

PAp, PBp, PCp, are Meridians.

ab, cd, ef, are Parallels of Latitude.

PGAp is the Prime Meridian of Greenwich.

Pap is the Meridian of 180° E. or W,

PSCp is the Meridian of S ; PBTp the Meridian of T.

cd is the Parallel of S ; ef the Parallel of T.

AC is the Longitude of S.	AB is the Longitude of T.
CS is the Latitude of S.	BT is the Latitude of T.

CB is the Diff. of Longitude between S and T.

SR is the Diff. of Latitude between S and T.

CHAPTER II.

THE TERRESTRIAL SPHERE.

The Primary Circle is the Equator.
The Secondary Circles are called Meridians.
Co-ordinates: Latitude and Longitude.

Earth's Axis The *Axis* of the Earth is that diameter about which it revolves, with an uniform motion from West to East.

Earth's Poles. The *Poles* of the Earth are the extremities of its axis.

The Equator. The *Equator* is the great circle whose axis and poles are the axis and poles of the Earth.

Meridians. *Meridians* are great circles which pass through the poles of the Earth.

Meridian of a Place. *The Meridian of a Place* on the Earth is that meridian which passes through the place.

The First or Prime Meridian. *The First* or *Prime Meridian* is that fixed Meridian by reference to which the Longitude of places on the Earth is measured.

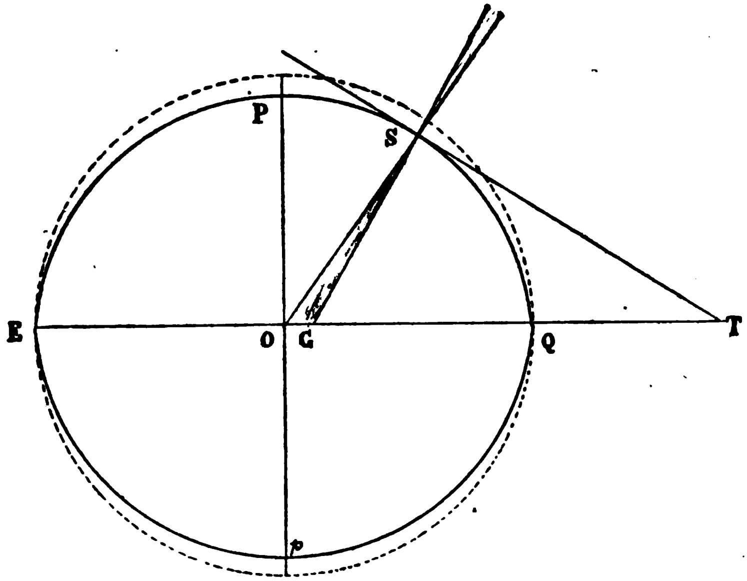
By general consent, the Meridian of Greenwich is now taken as the Prime Meridian.

Parallels of Latitude. *Parallels of Latitude* are small circles whose planes are parallel to the plane of the Equator.

Longitude of a place. *The Longitude of a Place* is the arc of the Equator intercepted between the first Meridian and the Meridian of the place.

Longitude is reckoned East or West from the first Meridian and may be of any magnitude from 0° to 180° E. or W.

A PROJECTION ON THE PLANE OF THE MERIDIAN.



P, p are the Earth's Poles; EQ, the Equator.

The figure of the Earth is represented by PQpE.

Its intersection with the plane of the Meridian differs from a circle because the earth is an oblate spheroid.

The perpendicular to the earth's surface at S is SG, which is perpendicular to the plane ST, touching the earth at S.

SGT is the True Latitude of S.

SOT is the Reduced Latitude of S.

Latitude of a Place.

The Latitude of a Place is the arc of a Meridian intercepted between the Equator and the place.

Latitude is reckoned North or South from the Equator and may be of any Magnitude from 0° to 90° N. or S.

Difference of Latitude.

The Difference of Latitude between two places is the arc of a Meridian, intercepted between their parallels.

This is called T.D. Latitude, in opposition to Mer. D. Lat., see page 13.

Difference of Longitude.

The Difference of Longitude between two places is the smaller arc of the Equator intercepted between their Meridians.

True Latitude.

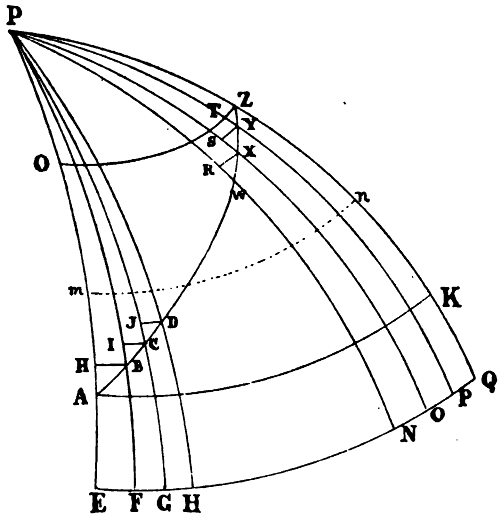
The True Latitude of a place is the angle between a perpendicular to the Earth's surface at that place and the plane of the Equator.

Reduced or Central Latitude.

The Reduced or *Central Latitude* of a place is the angle between the Earth's Radius at that place, and the plane of the Equator.

The difference between the True and Reduced Latitudes is always small, being due to the fact that the Earth is not quite, though very nearly, a sphere. If the Earth be regarded as a sphere the definitions of True and Reduced Latitude will both agree with the definition of Latitude given above.

FIGURE TO ILLUSTRATE DEPARTURE.



P is one of the Earth's Poles.

AZ is the Rhumb Line between A and Z.

A, B, C, D, ... W, X, Y, Z, are some of an infinite number of points on the Rhumb Line.

PA, PB, PC, &c., &c., are the Meridians through each of them.

The Angles PAB, PBC, PCD, . . . PWX, PWY, PYZ, are all equal as AZ is a Rhumb Line, and these angles are called *the Course* sailed between A and Z.

AZ is the Distance between A and Z.

The sum of the small portions of Parallels HB, IC, SD, . . . RX, SY, TZ, make up the Departure.

mn is the arc of a parallel equal to the Departure.

Em is the True Middle Latitude.

CHAPTER III.

NAVIGATION.

Nautical Mile.

A Nautical Mile is equal to the mean length of a minute of Latitude, and is reckoned at 6080 feet.

Rhumb Line.

A Rhumb Line is a curve which cuts all meridians at the same angle.

Course.

The *Course* of a ship on a Rhumb Line is the angle which the Rhumb Line makes with any meridian.

Distance.

The *Distance* between two places is the length of the Rhumb Line joining them, expressed in Nautical miles.

Departure.

The *Departure* between two places is the amount of Easting or Westing made in sailing between them on a Rhumb Line.

If an infinite number of points be taken on the Rhumb Line, the meridian through each of these points cuts off an arc of the parallel of Latitude through the next point. The sum of all these arcs is called the *Departure.*

Middle Latitude.

The Middle Latitude of two places on the same side of the Equator is half the sum of their latitudes.

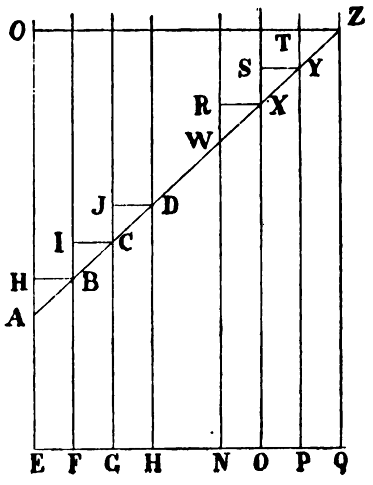
The term is not strictly applicable to places on opposite sides of the Equator.

Traverse.

When a ship sails on two or more courses she is said to describe *a Traverse.*

MERCATOR'S CHART.

(See also Figure for Departure.)



OEQZ is a portion of a Mercator's Chart, in which the Meridians AE, BF, CG, ... WN, XO, YP, ZQ are represented by straight lines.

The Rhumb Line AZ, since it cuts them all at the same angle, i.e., *the Course*, is represented by a straight line.

At any place, the small arc of latitude AH is expanded on the Chart in the same proportion as the arc HB of the parallel has been expanded. HB in the Departure Figure has been expanded to become equal to EF, and AH is expanded in the same proportion.

Mercator's Chart.

A Mercator's Chart is a Chart constructed on the following principles.

(1.) Meridians are represented by parallel straight lines.

Hence (*a*) a Rhumb Line, since it cuts all meridians at the same angle, is represented by a straight line. (*b*) Each parallel of Latitude is expanded to the same length as the Equator.

(2.) At any place the small arc of Latitude is increased in the same proportion as the small arc of the parallel.

Hence the scale of the chart at any place is equal to the scale of the chart at the Equator × sec. lat.

Meridional Parts.

The Meridional Parts of a certain Latitude give the length expressed in Nautical miles of the line on the Mercator's Chart, which represents the Latitude.

Mer. Diff: Lat.

The Meridional Difference of Latitude between two places is the length expressed in Nautical miles of the line on the Mercator's Chart, which represents the difference of Latitude.

Plane Sailing.

Plane Sailing is the method of solving problems in Navigation in the case of a ship sailing on a Rhumb Line by the use of the plane triangle, which represents the relations between the Course, Distance, Departure, and T.D. Latitude,

Traverse Sailing.

Traverse Sailing is the method of solving problems in Navigation in the case of a ship which is sailing on several courses.

Mercator's Sailing.

Mercator's Sailing is the method of solving problems in Navigation in the case of a ship sailing on a Rhumb Line, by the aid of Mercator's Chart and the table of Meridional parts constructed for it.

Parallel Sailing.

Parallel Sailing is the method of solving problems in Navigation when a ship is sailing due East or West, that is, on a parallel of Latitude.

Mid. Lat. Sailing.

Middle Latitude Sailing is the method of solving problems in Navigation in the case of a ship sailing on a Rhumb Line, on the assumption that she would make the same departure by sailing on a parallel of middle latitude.

The Latitude, in which the Meridian Distance is exactly equal to the Departure, is sometimes called TRUE MID. LAT.

Great Circle Sailing.

Great Circle Sailing is the method of solving problems in Navigation in the case of a ship sailing on a Great Circle.

The Distance on the Great Circle is the shortest distance between two places.

Vertex of a Great Circle.

The Vertex of a Great Circle is the point in it which is nearest to the Pole.

At the Vertex the Meridian and the Great Circle intersect at right angles. It must be noted that a Great Circle between two places has two vertices. A convention is made that the Vertex is used which is on the same side of the Equator as the place of higher latitude.

Leeway.

Leeway is the angle between a ship's fore and aft line and her wake.

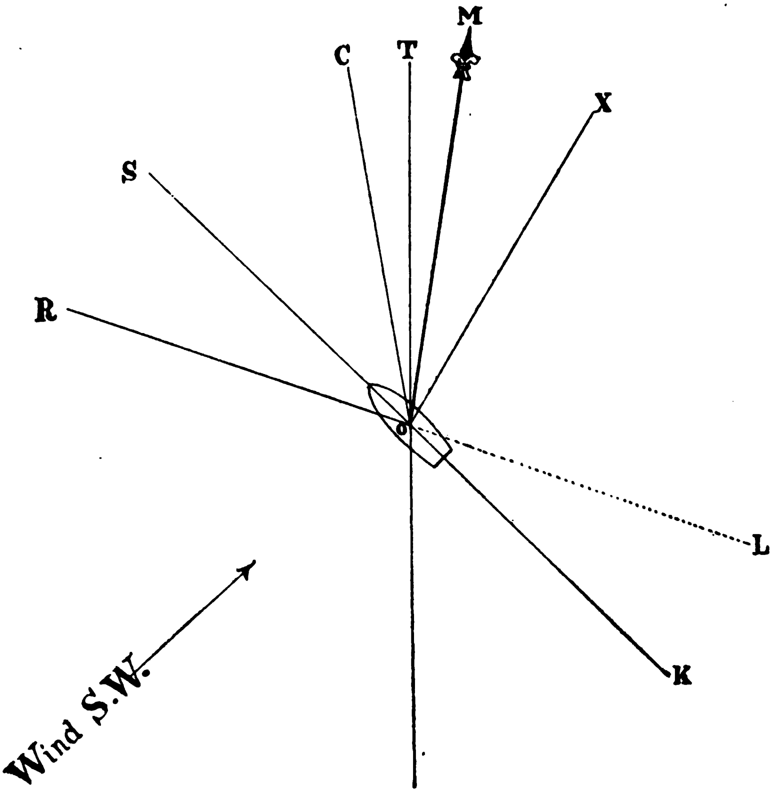
Set and Drift of a Current.

The Set of a Current is its direction, and is named after the point to which it is running.

The Drift of a Current is the distance through which it flows in a given time.

Magnetic Meridian.

The Magnetic Meridian is the Great Circle in which the Compass Needle lies when unaffected by local attraction.



OT is the Meridian of the place.
OM is the Magnetic Meridian
OC is the direction of the Compass Needle.
MOT is the Variation.
COM is the Deviation.
TOC is the Compass Error.
KOL is the Leeway.
TOS is the True Course Steered.
MOS is the Magnetic Course Steered.
COS is the Compass Course Steered.
TOR is the True Course made good.
MOR is the Magnetic Course made good.
TOX is the True Bearing of X.
MOX is the Magnetic Bearing of X.
COX is the Compass Bearing of X.

Variation. *The Variation* is the angle between the Magnetic Meridian and the Meridian of the place.

Deviation. *The Deviation* is the angle between the Compass Needle and the Magnetic Meridian.

Deviation is the effect of local disturbing forces.

Compass Error. *The Compass Error* is the angle between the Compass Needle and the Meridian of the place.

The Compass Error is the Algebraic Sum of Variation and Deviation.

Dip of the Needle. *The Dip of the Needle* is the angle between the horizontal plane and a magnetic needle freely suspended at its centre of gravity.

True Course Steered. *The True Course Steered* is the angle between the ship's fore and aft line and the Meridian of the place.

True Course made good. *The True Course made good* is the angle between the Rhumb Line sailed and the Meridian of the place.

True Bearing. *The True Bearing* of an object is the angle between the Meridian and the Great Circle, which passes through the object and the observer.

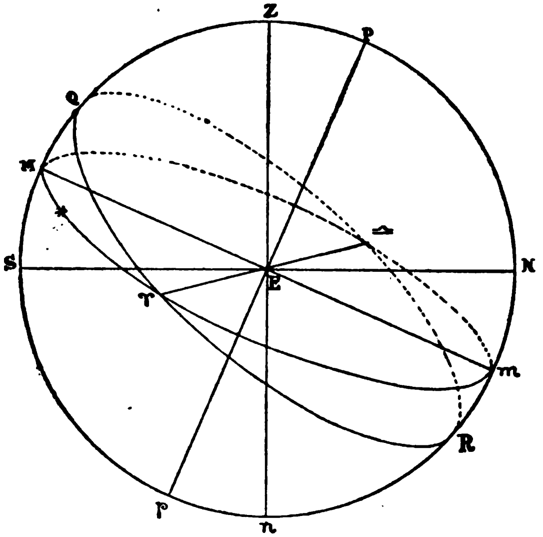
NOTE.—*In the expression* True Bearing and Distance, *which is used in the Logs of H.M. Ships,* True Bearing *signifies* True Course *to the place indicated.*

The COURSES STEERED *or* MADE GOOD *and the* BEARINGS *of objects are termed* TRUE, MAGNETIC, *or* COMPASS, *according as they are referred to the Meridian of the place, the Magnetic Meridian, or the direction of the Compass Needle.*

Cross Bearings. *Cross Bearings* are the bearings of two objects taken from the same place.

The intersection of the lines of bearing fixes the point of observation on a Chart.

PROJECTION ON PLANE OF MERIDIAN.



This figure represents a projection of the Celestial Concave on the plane of the Meridian, with the Ecliptic and Equinoctial represented in full, *(the part on the further side of the Meridian being dotted.)*

The Sun is at ✱, and the first point of Aries is in the East; hence the time represented is about 10 a.m. on the 1st of February.

E is the Earth.

Pp is the Axis of the Heavens. P, p are its Poles.

Q♈R≏ is the Equinoctial.

SQZPN is the Celestial Meridian.

M♈m≏ is the Ecliptic

M and m are the Solstitial Points.

Q♈M is the Obliquity of the Ecliptic.

CHAPTER IV.

CELESTIAL CONCAVE.

Celestial Concave.

The Celestial Concave is the surface of an infinitely large sphere, of which the earth is the centre, and on which the motions of the heavenly bodies appear to take place.

Place of a Body.

The True Place of a Body is the point in which the line joining the centre of the earth to the centre of the body, meets the Celestial Concave.

Apparent Place.

The Apparent Place of a Body is the place in which its centre is seen on the Celestial Concave by an observer.

Axis of the Heavens.

The Axis of the Heavens is coincident with the Earth's Axis produced.

It is about this diameter that the Celestial Concave appears to revolve from East to West.

Poles of the Heavens.

The Poles of the Heavens are the Extremities of the Axis.

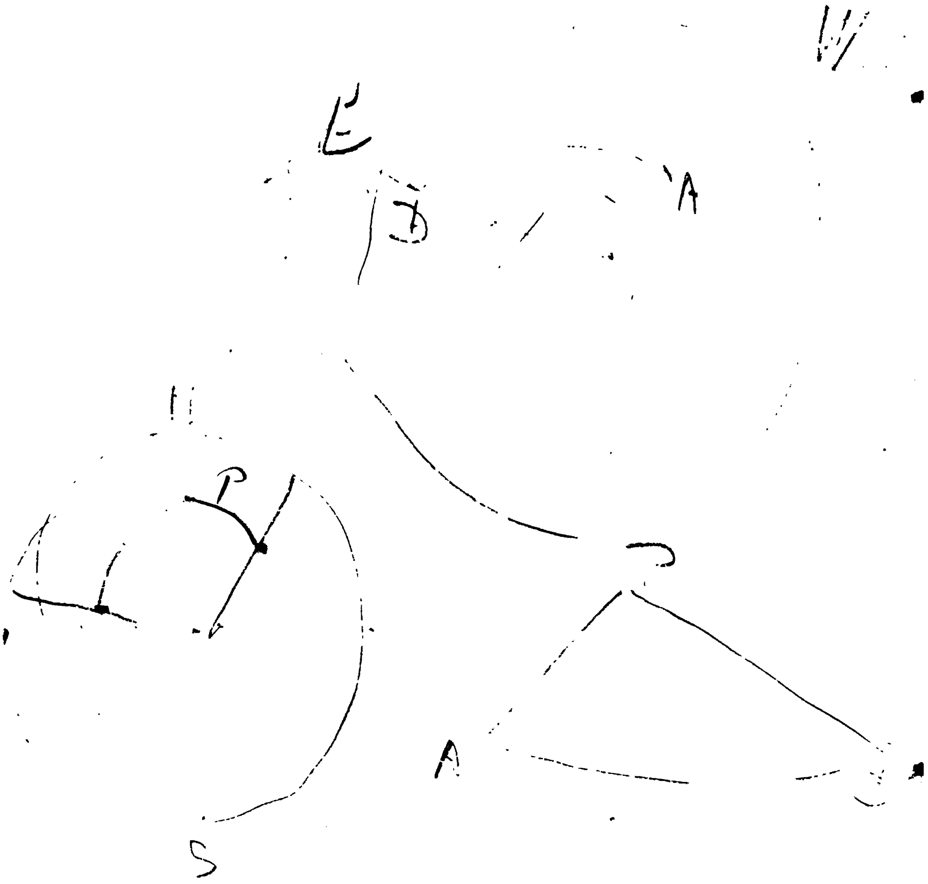
Equinoctial.

The Equinoctial or Celestial Equator is the great circle in which the plane of the Terrestrial Equator cuts the Celestial Concave.

Its Axis and Poles are the Axis and Poles of the Heavens.

Celestial Meridian.

The Celestial Meridian is the great circle in which the plane of the Terrestrial Meridian cuts the Celestial Concave.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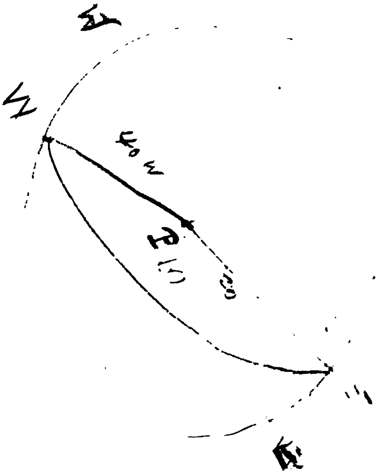
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Earth's Orbit.

The Earth's Orbit is a plane and nearly circular curve described about the Sun.

Ecliptic.

The Ecliptic is the great circle in which the plane of the Earth's Orbit cuts the Celestial Concave.

It is the great circle on which the Sun appears to move during the year.

Obliquity of the Ecliptic.

The Obliquity of the Ecliptic is the angle between the Ecliptic and the Equinoctial.

Its value may be assumed to be 23° 27′.

First Point of Aries.

The Ecliptic cuts the Equinoctial in two points : that in which the Sun passes from the South to the North of the Equinoctial, is called *the First Point of Aries.*

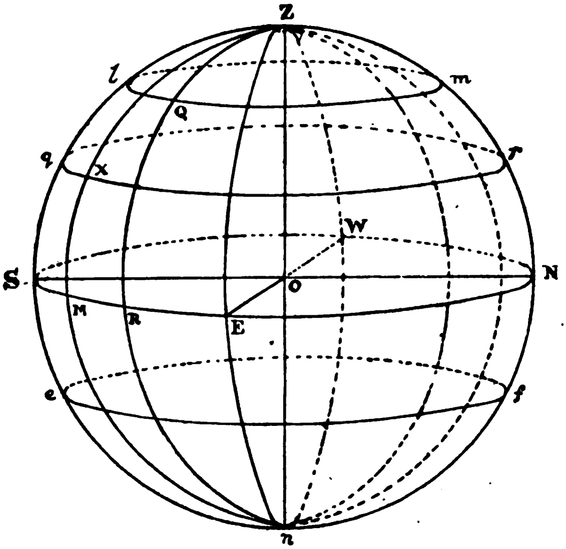
This point is called the Vernal Equinox, while the other point of intersection is called the Autumnal Equinox or *First Point of Libra.*

Solstitial Points.

The Solstitial Points are the two points of the Ecliptic which are at the greatest distance from the Equinoctial.

These points are midway between the Equinoxes.

When the Sun is near the Solstitial points its declination does not appreciably change for several days. Hence the name *Solstice.*



NESW is the Horizon.

Z is the Zenith ; n is the Nadir.

ZSnN is the Celestial Meridian.

ZQRn is a Vertical Circle or Circle of Altitude.

lQm, qXr are Parallels of Altitude.

N and S are the North and South Points.

E and W are the East and West Points.

MX is the Altitude of X ; RQ is the Altitude of Q.

ZX is the Zenith Distance of X ; ZQ is the Zen. Dist. of Q.

CHAPTER V.

THE HORIZON SYSTEM.

The Primary Circle is the Horizon.

The Secondary Circles are called Circles of Altitude or Vertical Circles.

Co-ordinates :—Altitude and Azimuth.

The Horizon

The Horizon at any place is the Great Circle in which the Celestial Concave is met by a plane touching the earth.

Sometimes the Horizon is thought of as determined by a plane through the centre of the Earth, parallel to the above plane, and it is then called the Rational or Theoretical Horizon, although it is absolutely identical with the Horizon defined above.

The Zenith

The Zenith is the point overhead in which the perpendicular to the plane of the Horizon at any place meets the Celestial Concave.

Reduced Zenith

The Reduced Zenith is the point overhead in which a radius of the Earth passing through the place of the observer, meets the Celestial Concave.

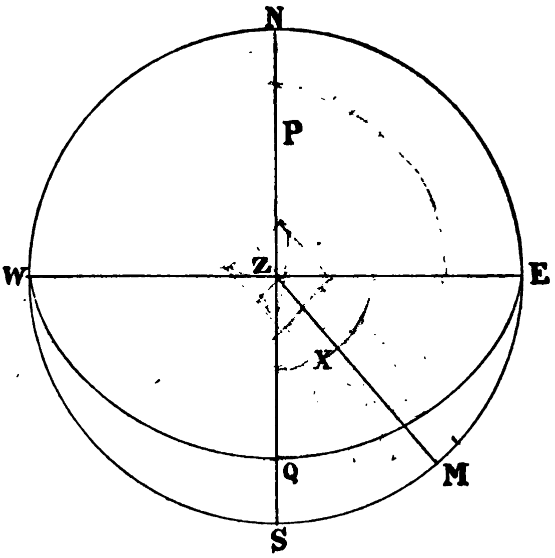
The True and Reduced Zenith are nearly coincident, the Earth being almost a sphere.

Nadir.

The Nadir is the point in the Celestial Concave diametrically opposite to the Zenith.

The Zenith and Nadir are the poles of the Horizon

A PROJECTION ON THE PLANE OF THE HORIZON.



Z is the Zenith; N, E, W, S are the Cardinal Points.

NZS is the Meridian.

WZE is the Prime Vertical.

P is the Pole; WQE is the Equator.

ZM is a Circle of Altitude.

XM is the Altitude of X; ZX is the Zenith Distance of X.

If X be the Sun, the figure represents the position of the Sun about 9 a.m. in June.

Circles of Altitude.

Circles of Altitude or Vertical Circles are great Circles which pass through the Zenith.

Parallels of Altitude.

Parallels of Altitude are small Circles whose planes are parallel to the plane of the Horizon.

The Celestial Meridian, as defined on page 19 is the great Circle which passes through the Zenith and the Poles of the Heavens.

North and South Points.

The North and South Points are the points in which the Celestial Meridian cuts the Horizon.

Prime Vertical.

The Prime Vertical is the Circle of Altitude whose plane is perpendicular to the plane of the Celestial Meridian.

East and West Points.

The East and West Points are the points in which the Prime Vertical cuts the Horizon.

Altitude.

The Altitude of a Heavenly Body is the arc of a Vertical Circle between the body and the Horizon

Zenith Distance.

The Zenith Distance of a Heavenly Body is the arc of a vertical Circle between the Zenith and the Body.

Angle of Elevation.

The Angle of Elevation of a body above the observer is the angle between a line drawn to it and the horizontal plane through the observer's eye.

Angle of Depression.

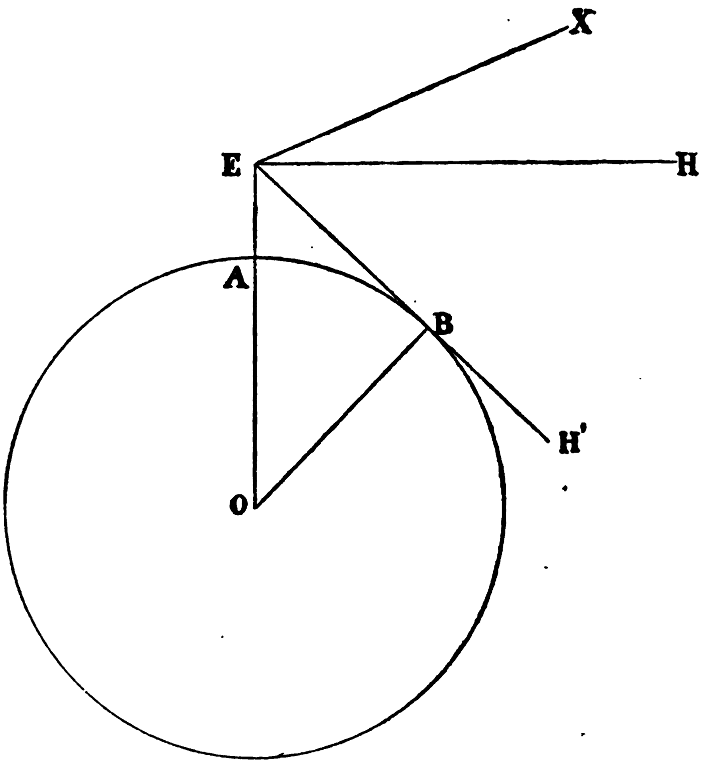
The Angle of Depression of a body below the observer is the angle between a line drawn to it and the horizontal plane through the observer's eye.

Azimuth.

The Azimuth or *True Bearing* of a Heavenly Body is the angle between the Celestial Meridian and the Circle of Altitude passing through the body.

It is measured by an arc of the Horizon from the N. or S. points either Eastward or Westward and may be of any value from 0° to 180°.

FIGURE FOR DIP.



HEB is the *Dip* or Angle of Depression of the Sea Horizon.

HEX is the Altitude or Angle of Elevation of X.

BEX is the Apparent Altitude of X.

Amplitude

The Amplitude of a Heavenly Body is the angle between the Prime Vertical and the circle of Altitude passing through the body when on the Horizon.

The Amplitude of a rising body is measured by an arc of the Horizon from the East point and may be of any value from 0° to 90° N. or S.

The Amplitude of a setting body is measured from the West point and may be of any value from 0° to 90° N. or S.

Twilight Parallel

The Twilight Parallel is a parallel of Altitude 18° below the Horizon.

Visible Horizon

The Visible or Sea Horizon is the small circle of the Celestial Concave which bounds the view of the observer, being the apparent meeting of the sea and sky.

Dip

The Dip is the angle of Depression of the Sea Horizon.

Note :—*The correction for Dip is —*

Refraction

The Correction for Refraction is the angle through which a ray of light from a body is deflected in passing through the earth's atmosphere.

The correction for Refraction is —; it vanishes at the Zenith, and is a maximum at the Horizon.

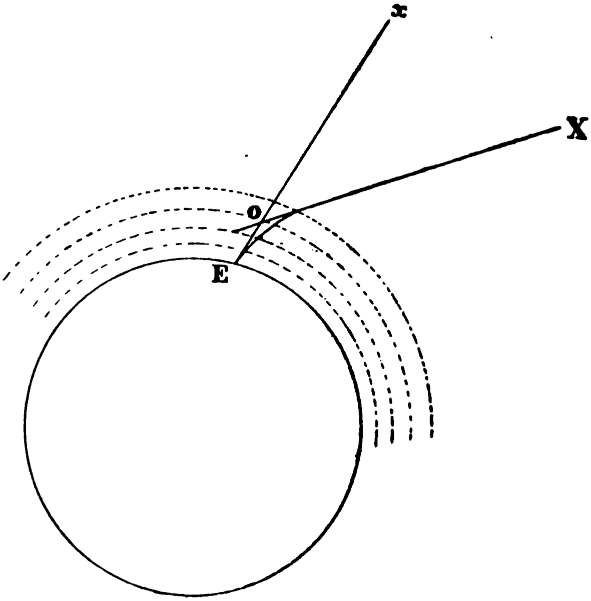
Parallax

Parallax is the apparent angular shifting of an object arising from a change in the point of view.

The Correction for Parallax in altitude is the angle subtended at the body by a radius of the earth passing through the observer.

The correction for Parallax is + ; it is a maximum in the Horizon and vanishes at the Zenith.

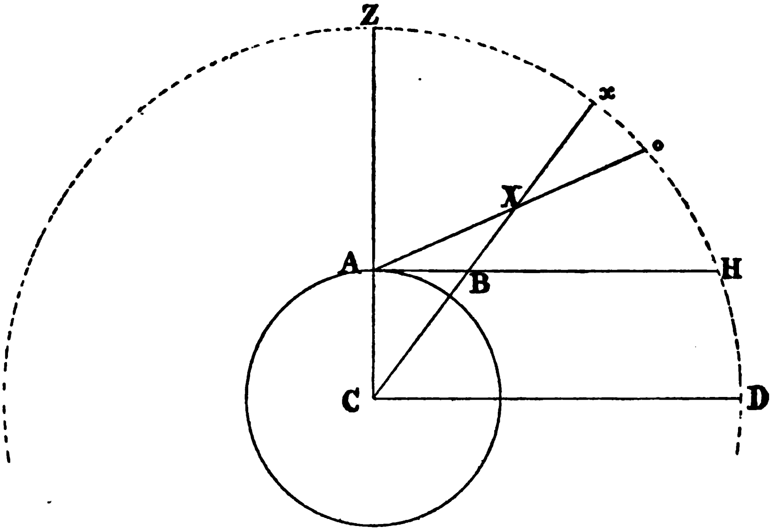
FIGURE FOR REFRACTION.



The ray of light from X is deflected by the Earth's Atmosphere through the angle XOx, so that the object is seen in the direction Ex, which is a tangent to the curved path of the ray at E.

XOx is the Correction for *Refraction.*

FIGURE FOR PARALLAX.



X is a Body.

x is the True Place of X on the Celestial Concave.

o is the observed place as seen from the Earth's Surface.

HXC is the Correction for Parallax.

HAX is the Apparent Altitude.

DCX is the True Altitude.

DCX = HBX.
= AXC + HAX.

True Alt. = Apparent Alt. + Parallax.

B

Observed Altitude

The Observed Altitude of a Heavenly Body is the altitude of the body above the Sea Horizon, as taken with a Sextant.

Apparent Altitude

The Apparent Altitude of a Heavenly Body is the observed altitude when corrected for Index Error, Dip, and Semi-Diameter; and is the angle of elevation of the line drawn from the observer to the apparent place of the body.

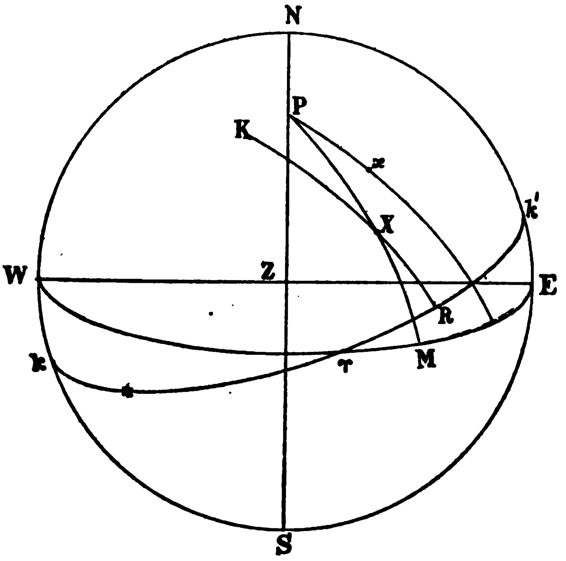
True Altitude

The True Altitude is the apparent altitude corrected for Refraction and Parallax; and is the angle of elevation of the line drawn from the centre of the earth to the true place of the body.

Transit

The Transit of a Heavenly Body is its passage over the Celestial Meridian.

PROJECTION ON THE PLANE OF THE HORIZON.



PM is a Circle of Declination.

♈ M is the Right Ascension of X.

MX is the Declination of X.

PX is the Polar Distance of X.

XPx is a Polar Angle.

ZPX measured Westward from the Meridian as indicated in the figure, is the Hour Angle of X.

Placing the Sun at ✱, the figure represents the Heavens about 4 p.m. at the end of January.

CHAPTER VI.

EQUINOCTIAL SYSTEM.

The Primary Circle is the Equinoctial or Celestial Equator.

The Secondary Circles are called Circles of Declination.

Co-ordinates :—Right Ascension and Declination.

Circles of Declination

Circles of Declination are great circles which pass through the poles of the Heavens.

Circles of Declination are sometimes called Hour Circles.

Parallels of Declination

Parallels of Declination are small circles whose planes are parallel to the planes of the Equinoctial.

Right Ascension

The Right Ascension of a Heavenly Body is the arc of the Equinoctial between the First Point of Aries and the Circle of Declination which passes through the body.

Right Ascension is measured IN TIME *Eastward, that is in the direction of the Sun's motion, and may be of any magnitude from 0h. to 24h.*

Declination

The Declination of a Heavenly Body is the arc of the Circle of Declination between the Equinoctial and the body.

Declination is measured from the Equinoctial, and may be of any magnitude from 0° to 90°, N. or S.

Polar Distance

The Polar Distance of a Heavenly Body is the arc of a Circle of Declination between the elevated Pole and the body.

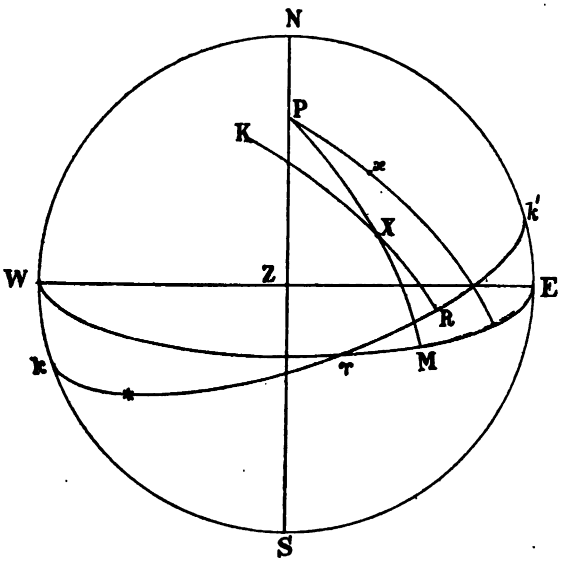
Polar Angle

A Polar Angle is the angle between any two circles of Declination.

Hour Angle

The Hour Angle of a Heavenly Body is the angle between the Celestial Meridian and the Hour Circle passing through the place of the body.

Hour Angle is measured Westward from the Celestial Meridian, and may be of any magnitude from 0h. to 24h.



K is the Pole of the Ecliptic k♈Rk′.

KXR is a Circle of Celestial Latitude.

♈R is the Celestial Longitude of X.

RX is the Celestial Latitude of X.

CHAPTER VII.

ECLIPTIC SYSTEM.

The Primary Circle is the Ecliptic.

The Secondary Circles are called Circles of Latitude.

Co-ordinates :—Celestial Latitude and Celestial Longitude.

Circles of Celestial Latitude.

Circles of Celestial Latitude are great circles passing through the poles of the Ecliptic.

Parallels of Celestial Latitude.

Parallels of Celestial Latitude are small circles whose planes are parallel to the plane of the Ecliptic.

Celestial Longitude.

Celestial Longitude is the arc of the Ecliptic between the First Point of Aries and the Circle of Celestial Latitude, passing through the place of the body.

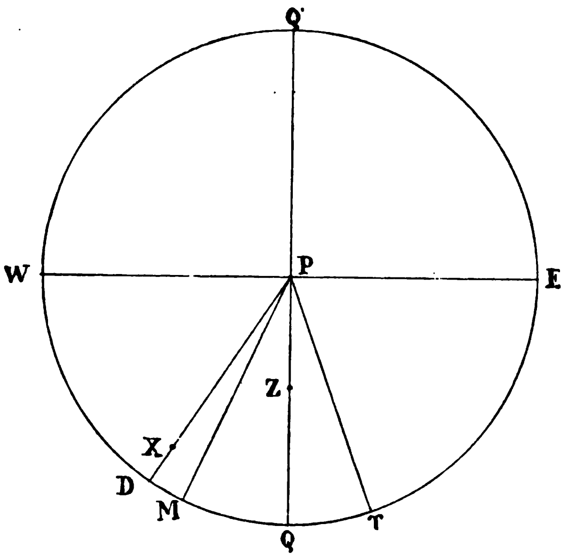
Celestial Longitude is measured Eastward, and may be of any magnitude from 0° to 360°.

Celestial Latitude.

Celestial Latitude is the arc of a Circle of Celestial Latitude between the Ecliptic and the place of the body.

Celestial Latitude is measured from the Ecliptic. and may be of any magnitude from 0° to 90° N. or S.

PROJECTION ON THE PLANE OF THE EQUINOCTIAL.



This Figure represents the Heavens about 2.30 p.m. on May 1st.

M is the Mean Sun; X is the Real Sun.

QPX is Apparent Time.

QPM is Mean Time.

MPX is the Equation of Time.

♈ EQ′WQ is the Sidereal Time.

CHAPTER VIII.

TIME.

Mean Sun.

The Mean Sun is an imaginary body, which is supposed to describe the Equinoctial with uniform velocity, in the same time that the real sun describes the Ecliptic with variable velocity.

Apparent Noon.

Apparent Noon is the instant when the centre of the real sun is on the Celestial Meridian.

Mean Noon.

Mean Noon is the instant when the mean sun is on the Celestial Meridian.

Apparent Time.

Apparent Time is the Hour Angle of the real sun.

Mean Time.

Mean Time is the Hour Angle of the mean sun.

Equation of Time.

The Equation of Time is the difference between the apparent and mean times.

Sidereal Time.

Sidereal Time is the Hour Angle of the First Point of Aries.

Apparent Solar Day.

An Apparent Solar Day is the interval of time between two successive transits of the sun over the same Celestial Meridian.

Mean Solar Day.

A Mean Solar Day is the interval of time between two successive transits of the mean sun over the same Celestial Meridian.

Sidereal Day.

A Sidereal Day is the interval of time between two successive transits of the First Point of Aries over the same Celestial Meridian.

Solar Year.

A Solar Year is the interval of time between two successive passages of the sun through the First Point of Aries.

Mean Solar Year.

A Mean Solar Year is the mean of several Solar Years.

Sidereal Year.

A Sidereal Year is the interval of time between two successive passages of the sun through the same point of the Celestial Concave.

Civil Time.

Civil Time is reckoned in two intervals of twelve hours, named A.M. and P.M., as they come before or after the noon of the day which begins at midnight.

Astronomical Time

Astronomical Time is reckoned in one period of 24 hours, beginning at noon.

Greenwich Date

The Greenwich Date is the Astronomical time at Greenwich of the instant when an observation is taken.

PARTS AND ADJUSTMENTS OF THE SEXTANT.

Names and Uses *of the different parts of the instrument.*

Index Glass (also called the first or movable reflector) for reflecting objects on to the Horizon Glass.

Horizon Glass (also called fixed reflector) for reflecting objects back to the observer's eye.

Index and Horizon Shades, for modifying the intensity of light from the sun, or any bright object.

Arc or Limb is divided at every ten minutes and on it, every half degree of arc is numbered as a whole degree, because the angle observed is double the angle of inclination of the index and horizon glasses.

Arc of Excess is that graduated portion of the arc to the right of Zero (generally 5°.)

N.B.—All small angles should be measured on the arc of excess, as well as on the arc, and the mean of these two readings gives the correct angle free from index error.

Index Bar connects index glasses with Vernier.

Vernier, (so-called from Inventor's name) is a small graduated scale sliding along the arc, by means of which it is possible to read off to a great degree of accuracy, in most sextants to 10″.

Clamping Screw, for securing Vernier to arc.

Tangent Screw, for giving a slow motion to the Vernier after it is clamped.

Collar, for receiving the telescope: it is made in two pieces for the adjustment of the line of Collimation.

The Line of Collimation is an imaginary line passing through the middle of the telescope; it is the optical axis of the telescope.

Adjusting Screws for the Line of Collimation are at the back of the collar, and, when making the adjustment, one of these screws must be loosened and the other tightened.

Up and Down Screw for raising or lowering the telescope until the reflected image of the object and the object itself are of the same brightness.

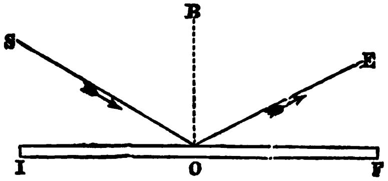
Adjusting Screw for Index Glass is at the back of the glass, and is for making it perpendicular to the plane of the instrument.

Adjusting Screws for the Horizon Glass are at the back of that glass; the upper one is for making it perpendicular to the plane of the instrument, and the lower one for making it parallel to the Index Glass where the Index points to Zero.

The Index is the arrow or Zero of the Vernier.

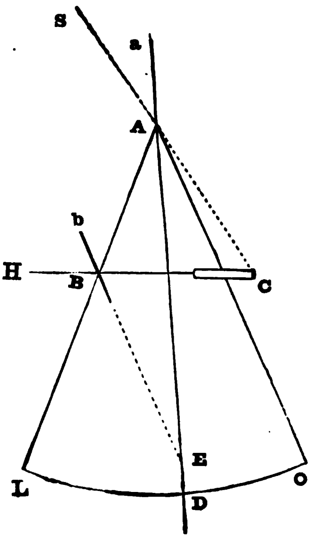
PROOF OF THE PRINCIPLE OF THE SEXTANT.

Note on Law of Reflection.



Let IF be a polished surface, SO a ray of light meeting it at the point O, and reflected in the direction OE; then SO is the incident ray, OE the reflected ray: and if BO is at right angles to the mirror, the angle SOB is the angle of incidence, and the angle BOE the angle of reflection. Now, since the reflection of light is governed by the law that the angles of incidence and reflection are equal to each other, it is evident that SOI (the complement of the angle of incidence) and EOF (the complement of the angle of reflection) are also equal.

The principle upon which the sextant is constructed is that "the angle between the first and last directions of a ray which has suffered two reflections in one plane, is equal to twice the inclination of the reflecting surfaces to each other."



Let the accompanying figure represent a sextant, and let S A be an incident ray of light falling upon the mirror Aa, then the ray is reflected at the point A, in the direction of the mirror Bb, when, upon striking it at the point B, the ray is again reflected, and in the direction BC; let SA be produced until it meets BC at C, then ACB is the angle between the *first* and *last* directions of the ray, and (if E is the point where the surfaces of the mirrors would meet if they were produced,) BEA is the angle of inclination of the reflectors.

To Prove that AOB is Twice BEA.

BAE is equal to SAa (*Law of Reflection*)

and SAa is equal to EAC (*Euc. I. 15.*)

$\therefore$ BAC is bisected by EA.

Again EBC is equal to ABb (*Law of Reflection*)

and LBE is equal to ABb (*Euc. I. 15.*)

$\therefore$ LBC is bisected by BE.

Now LBC is equal to BAC + ACB (*Euc. I. 32.*)

$\therefore$ LBE (or $\frac{1}{2}$ LBC) = BAE (or $\frac{1}{2}$ BAC) + $\frac{1}{2}$ ACB.

LBE is equal to BAE + BEA = BAE + $\frac{1}{2}$ ACB

$\therefore$ BEA = $\frac{1}{2}$ ACB.

The ray of light from the object S after reflection at A and E is seen in the direction BC, so that it coincides with the ray of light HBC from an object if seen directly through the clear part of the horizon glass; thus when the objects are seen to coincide, one seen directly in the direction HBC, and the other by reflection, the angle between them HCS is twice the angle BEA.

Since BE is parallel to AO, BEA = EAO. (*Euc. I. 29.*) Therefore the angle HCS between the object seen directly and reflected is twice the angle DAO.

Since DO is the measure of the angle DAO, it therefore measures half the angle HCS. But every half degree on the arc LOC is marked as, and *called* a degree, so that the real value of the angle HCS is read off directly on the arc, and the inconvenience of doubling the reading is avoided.

ADJUSTMENTS OF THE SEXTANT.

1ST.—The Index Glass should be perpendicular to the plane of the instrument.

2ND.—The Horizon Glass should be perpendicular to the plane of the instrument.

3RD.— The Line of Collimation should be parallel to the plane of the instrument.

4TH.—The Horizon Glass should be parallel to the Index Glass when the Index points to Zero.

N.B.—If the Index does not point to Zero when the Horizon Glass is parallel to the Index Glass, the Sextant has an error called the *Index Error.*

METHOD OF MAKING SEXTANT ADJUSTMENTS.

1ST.—Place the Index about the middle of the arc, and, looking obliquely into the index glass, observe whether the true and reflected limbs of the instrument form one continuous arc, if so, the index glass is perpendicular to the plane of the instrument; but if not, there is (in some Sextants) a screw at the back of the glass for adjusting it. In Sextants which have no adjusting screw the instrument must, if the index glass is not perpendicular to the plane of the instrument, be sent to the makers.

2ND.—Place the Index at about Zero, and looking at some distant well-defined object (the sun is best) observe when moving index about Zero whether the reflected image of the object exactly coincides with the object itself when passing over it; if so the horizon glass is perpendicular to the plane of the instrument, but if not it must be adjusted by the adjusting screw.

N.B.—Sextant held vertically

3RD.—Screw inverting telescope into the collar, and turn eye piece round so as to have two of the wires parallel to the plane of the instrument; measure the angular distance between two distant well-defined obects whose angular distance exceeds 90°, (sun and moon are best) bringing them into perfect contact at the wire nearest the plane of the innstrument, shift them to other wire by slightly moving instrument, and if contact remains perfect the line of Collimation is parallel to the plane of the instrument; but if not it must be adjusted by adjusting screws, loosening one and tightening the other until contact remains perfect at both wires. If objects separate at wire furthest from the plane of the instrument, the object end of telescope inclines towards the plane of the instrument and *vice versâ.*

N.B.—Sextant held horizontally.

4TH.—Place the Index accurately at Zero, and looking at the sea horizon observe whether the true and reflected horizons are in the same straight line; if so the horizon glass is parallel to the index glass, but if not it can be adjusted by the adjusting screw.

N.B.—Sextant held vertically.

METHOD OF ASCERTAINING AMOUNT OF INDEX ERROR OF THE SEXTANT.

1ST.—*The Horizon Method.*

Place the Index accurately at Zero, and, looking at the sea horizon, observe whether the true and reflected horizons are in the same straight line; if so there is no index error: but, if not, bring them into the same straight line by tangent screw: the amount of arc shown by index is the Index Error; + to the right, − to the left of Zero.

2ND.—Method by measuring sun's diameter *on* and *off* the arc.

Place the Index at about 30′ of arc (that being about the sun's diameter) and measure the sun's diameter (by bringing the limbs of the true and reflected suns into contact), then place index at about 30′ off the arc and again measure the sun's diameter; half the difference between these two readings will be the amount of index error: + if the greater reading is to the right of Zero, and − if to the left.

If both readings are on the same side of Zero half their sum is the amount of Index Error.

To prove correctness of this: divide the sum of the readings by four, and compare result with the semi-diameter for the day in the Nautical Almanac.

EXAMPLE OF INDEX ERROR.

On September 12th, 1890, the Sun's Diameter measured *on* the arc of a Sextant 33′ 0″, and *off* the arc 30′ 40″; find the Index Error of the Sextant.

Sun's diameter on arc	33′	0″
Do. Do. off	30	40
2 /	2	20
Index Error	− 1	10

PROOF.

Sun's diameter on arc	33′	0″
Do. Do. off arc	30	40
4 /	63	40
Semi-diameter by Sextant	15	55
Semi-diameter from Nautical Almanac	15	54·6

FORMULA FOR THE VERNIER.

In forming a Vernier of any instrument a number of divisions are taken from the scale of the instrument as length of Vernier, and on it this space is divided into a number of equal parts, differing by 1 (one) from the number taken.

Thus, if n be the number of divisions on the Vernier, then $(n + 1)$ or $(n - 1)$ will be the number of divisions taken from the scale of the instrument.

The degree of accuracy to which it is possible to read off by means of the Vernier is always equal to the length of a division on the scale of the instrument divided by the number of divisions on the Vernier.

If L represent the length of a division on the scale of the instrument, and n the number of divisions on the Vernier, the degree of accuracy $= \frac{L}{n}$

VERNIER FOR SEXTANT.

In forming the Vernier for a Sextant whose arc is divided at every 10′, if the required degree of accuracy be 10″, either 59, 61, 119 or 121 divisions must be taken from the arc and be divided on the Vernier into 60 equal parts.

The number usually taken is 119; the objection to taking 61 or 121 being that the Vernier would have to be read backwards; and the objection to taking either 59 or 61 being that the divisions on the Vernier would be very close together.

The length of a division on the Vernier of a Sextant is 19′ 50″.

Formula.± Degree of Accuracy $= \frac{L}{n}$

Let n = the number of divisions on the Vernier.

Then $(n \pm 1)$ = number of divisions taken from scale of instrument

Let L = the length of a division on scale of instrument.

Let V = the length of a division on scale of Vernier.

1st.—If $(n - 1)$ be the number of divisions taken

$$L(n - 1) = Vn$$

$$\therefore V = \frac{n - 1}{n} L$$

Degree of Accuracy.
$$L - V = L - \frac{n-1}{n} L$$
$$= \frac{nL - (n - 1) L}{n}$$
$$= \frac{nL - nL + L}{n}$$
$$= \frac{L}{n}$$

2nd.—If $(n + 1)$ be the Number of Divisions taken
$$L (n + 1) = Nn$$
$$V = \frac{n+1}{n} L$$

Degree of Accuracy.
$$V - L = \frac{n+1}{n} L - L$$
$$= \frac{Ln + L - nL}{n}$$
$$= \frac{L}{n}$$

3rd.—If $(pn - 1)$ be the number of divisions taken,
$$L (pn - 1) = Vn$$
$$V = \frac{L (pn - 1)}{n}$$

Degree of Accuracy
$$pL - V = pL - \frac{L (pn - 1)}{n}$$
$$= \frac{pLn - pLn + L}{n}$$
$$= \frac{L}{n}$$

Similarly if $(pn + 1)$ be the number taken.
$$\text{Degree of Accuracy} = \frac{L}{n}$$

To construct a Vernier. Example—

The arc of a Sextant is divided at every 10′, and the Vernier enables it to be read off to the nearest 15″.

Show how to construct it.

$$\text{Degree of Accuracy} = \frac{L}{n}$$

$$15'' = \frac{10'}{n}$$

$$15'' \times n = 10' = 600''$$

$$\therefore n = \frac{600}{15}$$

$$n = 40$$

Therefore either 39 or 41 divisions must be taken from the arc of the Sextant and be divided into 40 parts; or any multiple of 40 ± 1 division may be taken if divided on Vernier into 40 equal parts.

Ascertaining Degree of Accuracy. Example—

Arc of instrument divided into 10′. 59 of these parts are made equal to 60 of the Vernier. In this case

$$\text{Degree of Accuracy } L - V = \frac{L}{n}$$

$$= \frac{L}{60}$$

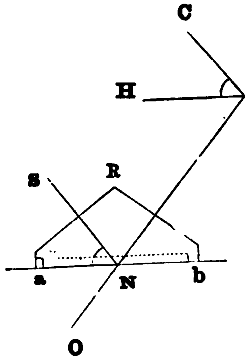
$$= \frac{10'}{60}$$

$$\text{Degree of Accuracy} = 10''$$

THE ARTIFICIAL HORIZON.

The artificial horizon is a reflector whose surface is perfectly horizontal; it is used for taking altitudes on shore.

The best kind of artificial horizon consists of an oblong trough, *a b*, filled with quicksilver, over which is placed a roof *a*R*b*; the sloping sides *a*R*b* are formed of plates of glass with parallel surfaces, the roof being intended to protect the surface of the mercury from disturbance by the wind.



Let SN be an incident ray from the Sun (or any other heavenly body whose altitude is required) falling upon *a b*, and reflected at N in the direction NE; then if the observer's eye be at E, the reflected image will appear in the direction ENO.

If CE be a direct ray to the observer's eye, and HE a line parallel to *a b*; then HEC is the altitude, and, when the sun or star is brought down to touch its image seen in the quicksilver, CEN is the angle observed.

Now since the distance of the sun or any other heavenly body may be considered as infinite in comparison with the distance EN, CE may be considered as parallel to SN.

∴ CEN is equal to SNO. (Euc. 1, 29.)

and as HE is parallel to *a*N.

∴ CEH is equal to SN*a*. (Euc. 1, 29.)

Since SN*a* is equal to EN*b* (Law of Reflection)

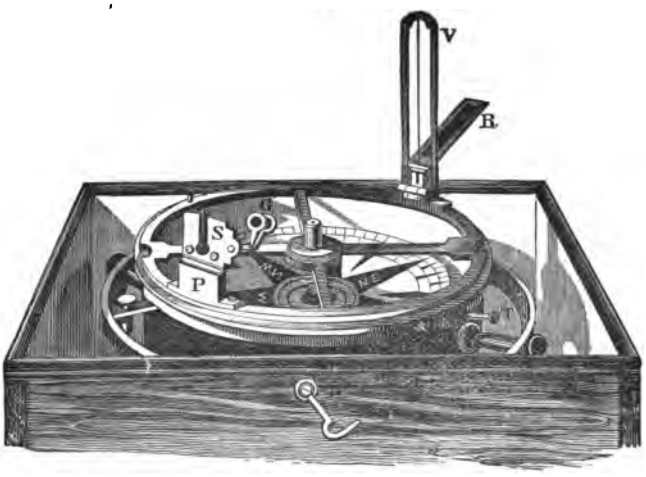
and *a*NO is equal to EN*b* (Euc. 1, 15.)

∴ SN*a* is equal to *a*NO.
∴ SNO is equal to 2 SN*a*.
and CEN is equal to 2 CEH.

That is, the angle observed with the artificial Horizon is twice the apparent altitude.

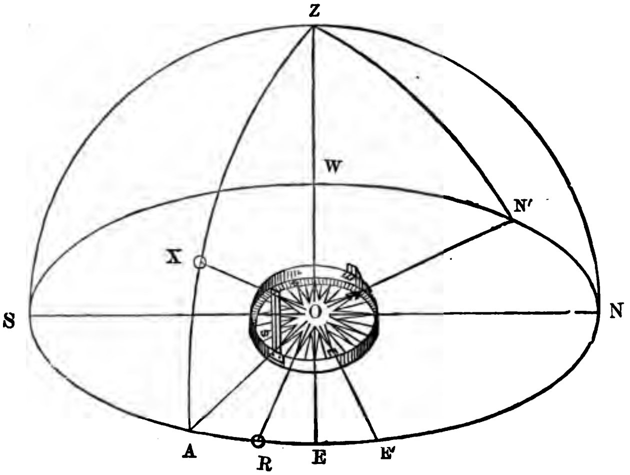
NOTE.—*The Index Error, if any, must be applied to the measured angle* CEN, *before halving it to obtain the apparent altitude* CEH : *and since* HEC *is a truly horizontal line, no correction for Dip must be applied to altitudes taken with the Artificial Horizon.*

THE AZIMUTH COMPASS.



The Reflector R is fitted with a hinge, to allow its face to be directed above or below the horizontal plane of the observer, in order that bearings of objects above or below this plane may be taken.

The eye vane S has a narrow slit forming the sight through which the vision is directed when taking a bearing. On looking through the circular hole at the lower extremity of this slit, and raising or lowering the prism P (attached to the sight vane) in its socket, distinct vision of the card and its divisions can be obtained, and the divisions are read by reflection in the prism.



Variation by Azimuth.—Let NWSE represent the horizon; Z the Zenith; NZS the meridian; ZN′ the magnetic meridian; O the centre of the horizon; X the sun above the horizon, and on the vertical circle ZXA; then will NA or NZX be his true azimuth, and N′A or N′ZX his magnetic azimuth; and

N′A—NA = NN′ = The Variation.
or N′ZA—NZA = NZN′ = The Variation.

Variation by Amplitude.—The true amplitude of R is the arc ER and the magnetic amplitude is E′R (for the compass amplitude observed is supposed to be corrected for deviation), therefore EE′ is the variation.

To determine whether the Variation of the Compass is East or West.—Draw a compass N.W.S.E., lay off on it the true bearing NR or the true amplitude ER, and from the line of bearing OR measure back towards North the magnetic bearing; it will then be seen on which side of the true North the needle points and the variation is East or West according as this is right or left.

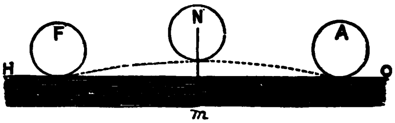
Deviation by Azimuth and Amplitude.—If N′ be the compass North, when the compass is affected by local forces, it is necessary to subtract the Variation N*a*′ on the chart from the Compass Error to find the Deviation.

TAKING ALTITUDES.

An unpractised observer experiences a difficulty in not knowing how to observe the Sun's *Meridian* Altitude, so as to take it at the moment of the Sun's being at its *highest* point for the day.

All the heavenly bodies *increase* in altitude from the time they rise until they come to the meridian, when they attain their *greatest* altitude; at this point they appear to be stationary for a few moments and then *decrease* in altitude until they set.

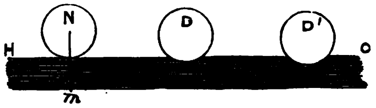
Thus, in taking the Sun's meridian altitude, it appears to rise continually until 12 o'clock, or apparent noon, when its altitude will be the highest, after which it appears to fall or dip; and how to secure the exact altitude when on the meridian, is the operation the accompanying figures are intended to explain.



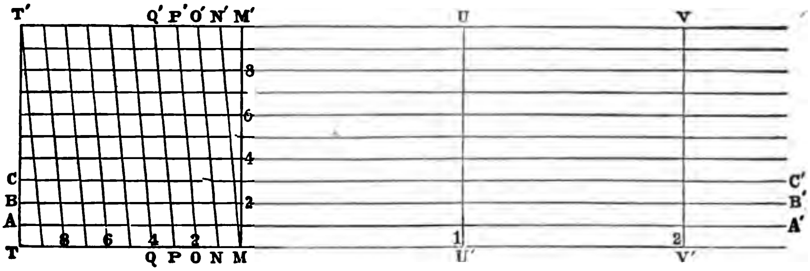
(Fig. *a*) HO is the horizon, F, N, A, the positions of the Sun at three separate times, F its position a few minutes *before* Noon, N its position at NOON, and A its position a few minutes *past* noon.

Supposing an observer to bring the Sun down so that its lower limb would exactly *touch* the horizon as in the position F, and to clamp the index of his sextant at this altitude, if he wait a little he will find that the Sun has *risen*, and is in the position N; if he wait a little longer, he will, on looking at the horizon, find that the Sun has *fallen*, and is in the position A.

As he has not moved the index of his sextant during all this time, he will have lost the *meridian* altitude, since the Sun in the interval has *risen* from F to N, and *fallen* from N to A.



(Fig. *b*) Supposing then that when he brought down the Sun's lower limb to the position F (Fig. *a*), he had continued to look at the horizon, and as the sun rose he gradually moved his tangent screw so as to keep the Sun's L. L. *touching* it, he would at noon have the Sun in the position N (Fig. *b*). Now if he still continued to watch the Sun, but did not move the tangent screw, he would find after a while that it has taken the position D, or that it has fallen a *little*, and in a minute or two more he would find it in the position D′, or that it had *dipped* and *passed* the meridian. The greatest altitude he would thus have obtained would be at N (Fig. *b*), which is the *meridian* altitude.



CONSTRUCTION AND USE OF THE DIAGONAL SCALE.

This scale derives its names from the lines MN′, NO′, &c., drawn *diagonally* across the longitudinal lines AA′, BB′, &c. It is divided into equal parts by the lines UU′, VV′, &c. There are *ten* longitudinal lines, AA′, BB′, &c., drawn at equal distances from each other. The division MT contains *ten* equal parts, MN, NO, OP, &c.; M′T′ is divided in the same manner, and the diagonal lines, MN′, NO′, OP′, &c., are drawn. The different divisions and subdivisions, and the longitudinal lines are numbered as shewn in the figure, but, because the numbers would come too close if all put down, only every second number (2, 4, 6, &c.) is engraved on the scale.

The principle of this kind of scale is this, that the diagonal line MN′ cuts off, between itself and the perpendicular line MM′, small portions of the longitudinal lines, which are respectively equal to $\frac{1}{10}$th, $\frac{2}{10}$ths, $\frac{3}{10}$ths, &c., of the division M′N′ or MN.

In using this scale *the two points of the dividers must always be placed on the same longitudinal line.* This being understood, suppose one point is on the perpendicular line numbered 2, and the other on the diagonal line numbered 6, also that *both* points are on the longitudinal line numbered 4. Then considering the division MN as unity, it is clear, from what has been said, that the two points of the compasses include two of the large divisions (each equal to ten times MN), six of the divisions equal to MN, and $\frac{4}{10}$ths of MN, that is, altogether $26\frac{4}{10}$ of MN, or 26.4, since MN is considered as unity.

Hence, in measuring with this scale, we have only to remember the following rules (in which we suppose the divisions MN, NO, &c., to be unity) :—

The number of the *perpendicular line* shows *tens.*
" " *diagonal line* " *units.*
" " *longitudinal line* " *tenths.*

If we wish to employ the scale in measuring higher numbers we can suppose each division to be multiplied by ten, then the number taken off as above would be 264, and so on. If for lower numbers, we can suppose each division to be divided by ten, then the number would be 2·64, &c.

RULE FOR DIAGONAL SCALE.

Measure, on the parallel line indicated by the 3rd figure, from the diagonal line indicated by the 2nd figure, to the vertical line indicated by the 1st figure.

SAMPLE OF THE WORKING OF A SHIP'S RECKONING

SAMPLE OF THE WORKING OF A SHIP'S RECKONING.

At noon, April 10th, 1890, a point of Land in Lat. 50° 30′ N. Long. 14° 10′ W., bore by compass N. W. by N., dist. 3 miles (deviation as for the direction of the ship's head); afterwards sailed as by the following log account; work up the reckoning to noon April 11th.

Hours.	Knots.	Tenths.	Standard Compass Courses.	L. W. Points.	Winds.	Deviation of Stand. Comp.	Remarks.
1	2	3	S.E. b S.	2	S.S.W.	3° E.	P.M.
2	2	4					
3	2	3					
4	2	3					
5	3	9					
6	4	5	W.N.W.	1½	S.W.	7° W.	At 6h 39m, p.m., Dev. by Amp.
7	4	0					
8	5	5					
9	5	5					
10	4	0					
11	4	4					
12	5	6	S.W.	0	S.E. b S.	7° W.	Midnight.
1	6	5					A.M.
2	7	0					
3	7	3					
4	6	6					
5	5	4	S. b E.	1	S.W. b W.	1° E.	8h. 30m., a.m. Sights for Long.
6	4	0					
7	5	5					
8	3	6					
9	4	0					
10	6	5	N.W. b W.	¼	S.W. b S.	6° W.	Noon. Obs. for Lat.
11	7	5					
12	8	0					

True Course and Distance.	Lat.	Long.	Variation allowed.	True Bearing and Distance. Terceira, Azores Lat. 38° 39′ N. Long. 27° 14′ W.
Current.	D.R. Obs.	D.R. Chron.	29° W.	

TO FIND THE LATITUDE AT NOON, APRIL 11th.

Obs. mer. alt. Sun's L.L. 48° 13′ 10″ (Z.N.); index error + 1′ 50″; height of eye 26 feet.

TO FIND THE LONGITUDE AT 8h 30m A.M., AND THENCE THE LONGITUDE AT NOON.

Time by Chron.	Obs. Alt. Sun's L.L.		
8h 46m 32s	29° 40′ 30″	Index error	+ 1′ 50″
8 46 50	29 43 20	Height of eye	26 feet.
8 47 8	29 46 10		

On March 21st, at G.M. Noon, the chronometer was slow on G.M.T. 0h 43m 20s, and its daily rate was 3·5 seconds gaining.

TO FIND THE VARIATION BY AMPLITUDE.

At 6h 39m P.M., the Sun set by standard compass W. 48° 53′ N. (deviation as for ship's head.)

DAY'S WORK.

Bearing and Dep. Co.	Dist = 3′	Position at Noon, April 10th.	
Bearing N. 34° W. Var. & Dev. 26 *l*	D. Lat = 1·5 S. Dep. = 2·6 E.	Lat. point 50° 30′ N. D. Lat. 1·5 S.	Long. point 14° 30′W. D. Long. 4 E.
Dep. Co. S. 60° E. 3′	D. Long. = 4·1 E.	Lat. Noon 50 28·5 .N.	Long. Noon 14 6 W.

	1	2	3	4	5
	S 33 45 *l*	N 67 30 *l*	S 45 *r*	S 11 15 *l*	N 56 15 *l*
Var. & Dev.	26 *l*	36 *l*	36 *l*	28 *l*	35 *l*
	59 45 *l*	103 30 *l*		39 15 *l*	91 15 *l*
Leeway	22 30 *l*	14 3 *r*		11 15 *l*	2 48 *r*
	S 82 15E	N 89 27 *l*	S 9 W	S 50 30 E	N 88 27 W
	13′.2	27′·9	33′	22′·5	22′

Course.	Dist.	N.	S.	E.	W.	Lat. D. R.	Long. D.R.
S 82° E	13.2	--	1.8	13.1	—	Lat. from 50° 28·5′ N.	Long. from 14° 6′W
N 89 W	27.9	0.5	—	—	27.9	D. Lat 47·6 S.	D. Long 39W
S 9 W	33.0	—	32.6	—	5.2		
S 50 E	22.5	—	14.5	17.2	—	Lat. D.R. 49° 41 N.	Long. D.R. 14 45W
N 88 W	22.0	0.8	—	—	22.0	100° 9·5′ N.	Diff. Long. =
		1.3	48.9	30.3	55.1	Mid. Lat. 50 4.7	Dep. × Sec. Mid. Lat
			1.3		30.3		1·397940 10·192649
		D. Lat.	47.6 S.	Dep.	24.8W	D. Long. 38·96 W.	1·590589

LATITUDE BY MER. ALT.

Gr. Date.			Declination.	Change.
	h.	m.		
Ship, April 11th	0	0	8° 24′ 14″ N.	
Long in time	0	59 W.	+54	+54″
Gr. April 11th	0	59	8 25 6N	

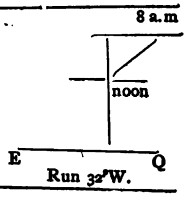
Obs. Alt.	48°	13′	10″	
I.E.		+ 1	50	
	48	15	0	
Dip,		− 5	1	
	48	9	59	
Semi.		+ 15	59	
	48	25	58	
Corr. in Alt.			−46	
True Alt.	48	25	12	
	90			
Z.D.	41	34	48	N.
Dec.	8	25	8	N.
Lat. Obs.	49	59	56	N.

Mean of sights for longitude.

	29°	40′	30″
		43	20
		46	10
3 /		130	0
Obs. Alt.	29°	43	20
	h.	m.	s.
	8	46	32
		46	50
		47	8
3 /		140	30
	8	46	50

WORKING BACK.

Course.	Dist.	N.	S.	E.	W.	Lat. at Sights.
						° ′ ″
N. 88°W	22·0	0·8	—	—	22·0	Lat. Obs. 49 59 56 N.
S. 50° E	2	—	1·3	1·5	—	D. Lat. 30 N.
			0·8		1·5	
		D. Lat. 0.5 S.		Dep. = 20·5 W, D. Long.=32 W		Lat. at Sights } 49 59 26N.



LONGITUDE BY CHRONOMETER.

Gr. Date.	G.M.T. by Chron.	Rate.
h. m.	h. m. s.	sec.
Ship April 10th, .. 20 30	Chron. Showed 8 46 50	—3·5
Long. in time .. 0 57 W.	Error .. .. 0 43 20 +	21
Gr. April 10th .. 21 27	9 30 10	35
	Rate .. .. — 1 13	70
	9 28 57	60 | 73·5
	12	1.13·5
From March 21st, 20 days 20½ hours	G.M.T. April 10 21 28 57	Gaining

Declination.	CHANGES from Noon April 11. Decl.	Eqn. T.	Eqn. of Time.
° ′ ″			m. s.
8 24 13 N.	— 55″.0	— ·68 sec.	1 1·0
— 2 17	2 .5	2·5	+ 1·7
8 21 56 N.	275	340	1 2·7
	110	136	
Semi .. .. 15′ 59″	60 / 137.5	+1·700	(Add to App. T.)
	— 2 17	1·7+	

	°	′	″
Obs. Alt. ..	29	43	20
I.E. ..	+	1	50
	29	45	10
Dip	—	5	1
	29	40	9
Semi	+	15	59
	29	56	8
Corr. in Alt.	—	1	33
T.A.	29	54	35
	90	0	0
Z.D.	60	5	25

	°	′	″		
Lat.	49	59	26	N. L. sec.	10·191857
Dec.	8	21	56	N. L. sec.	10·004647
	41	37	30		
	60	5	25		
	101	42	55	½ L. Hav.	4·889630
	18	27	55	½ L. Hav.	4·205350
				L. Hav. A.T. =	9·291484

	d.	h.	m.	s.
Ship App. Time April	10	20	29	59
Eqn. Time ..			1	3 +
S.M.T. ..		20	31	2
G.M.T. ..		21	28	57
		0	57	55

Long. at Sights ..	14° 28′ 45″W
Run ..	32 0 W
Long. Obs.	15 0 45W

BEARING AND DISTANCE.

	° ′			° ′
Lat. obs ..	50 0 N.	3474·47	Long. obs. ..	15 1 W.
Lat. to ..	38 39 N.	2517·97	Long. to ..	27 14 W.
	11 21 S. 60	956·50		12 13 W. 60
D. Lat. ..	681 S.		D. Long. ..	73·3 W.

Tan. Co. $= \dfrac{\text{D. Long.}}{\text{M. D. Lat.}}$

Dist. = D. Lat. × Sec Co.

12·865104	10·100315
2·980685	2·833147
9·884419	2·933462

Course to or Bearing of Terceira S. 37° 28′ W.

Distance 858 miles.

COURSE AND DISTANCE MADE GOOD.

	° ′			° ′
Lat. from ..	50 28·5 N.	3519·03	Long. from ..	14 6 W
Lat. obs. ..	50 0 N.	3474·47	Long. obs. ..	15 1 W
D. Lat. ..	0 28·5 S.	44·56	D. Long. ..	55 W.

Tan. Co. $= \dfrac{\text{Diff. Long.}}{\text{M. D. Lat.}}$

Dist.=D. Lat. × Sec. Co.

11·732363	10·195610
1·648945	1·454845
10·083418	1·650455

Course = S. 50° 24′ W.

Distance = 44·7 miles

CURRENT.

	° ′		°
Lat. D. R. ..	49 41 N.	Long. D. R. ..	14 45 W.
Lat. obs. ..	50 0 N.	Long. obs. ..	15 1 W.
D. Lat. ..	19 N.	D. Long. ..	16 W.
		(Dep. ..	10·3)

Set N. 28° W. Drift 22 miles.

DEVIATION BY AMPLITUDE.

(SETTING.)

Course.	Dist.	N.	S.	E.	W.	Lat. in	Long. in
S. 82 E.	13.2	—	1.8	13.1	—	Lat. from 50° 28.5′ N.	Long from 14° 6′W.
N. 89 W.	7.	0.1	—	—	7.0	D. Lat. 1.7 S.	D. Long. 10 E.
			1.8 .1	13.1 7.0		Lat. in 50 27 N.	Long. in 13 56 W.
		D. Lat.	1.7 S.	6.1	=	D. Long. 10 E.	

Gr. Date.	Declination.	Change.
h. m. Ship Ap. 10th, 6 39 Long. 56W. Gr. Ap. 10th 7 35	° ′ ″ 8 2 9 N + 6 58 8 9 7 N Lat. = 50° 27′ N.	55″+ 7.6 330 385 60 / 418 6′ 58″+
Sin. Amp. = Sin. Dec. × Sec. Lat. 9.151630 10.196030 9.347660 T. Amp. = W. 12° 52′ N.	T. Amp. = W. 12° 52′ N. 90 0 N. T. Bearing = N. 77 8 W. Variation = 29 0 W. Mag. B. = N. 48 8 W. Comp. ,, = N. 41 7 W. Deviation = 7° 1′ W. 1′ Ship's head W.N.W.	Comp Amp, = W. 48° 53′ N. 90 0 N. ,, Bearing = N. 41 7 W.